# THE PERIOD DISTRIBUTION OF CLOSE BINARY SYSTEMS

L. Mantegazza, P. Paolicchi, P. Farinella and F. Luzny
Osservatorio Astronomico di Brera, Merate, Italy

ABSTRACT. The analysis of the period distribution of eclipsing and spectroscopic binary systems shows the presence of some secundary maxima, which cannot depend on selection effects. These secundary maxima are mainly due to late type stars, as can be seen from the distribution curves for eclipsing binaries of various spectral types. The average separation of the components (in units of the sum of stellar radii) increases with the spectral type from O types to late B types, remaining almost constant for later spectral types.

The period distribution of close binaries (i.e. eclipsing and spectroscopic systems) was first studied by Fracastoro (1954) and then, with more recent catalogue data, by the present authors (Farinella and Paolicchi, 1978, Farinella et al., 1979, hereinafter referred as Papers I and II).

In principle one could represent the distributions either with equal steps in the period P or in the logarithm of the period, resulting in different shapes (the "linear" distribution is monotonically decreasing, while the logarithmic one has a sharp peak for periods of about 3 days and shows also some evidence of other local maxima). In the following, as previously done by Fracastoro and in Papers I and II, we shall employ the logarithmic representation, which seems to be more meaningful when one is concerned with problems of period variations with time, which are often of the form $\Delta P/P = f(t)$.

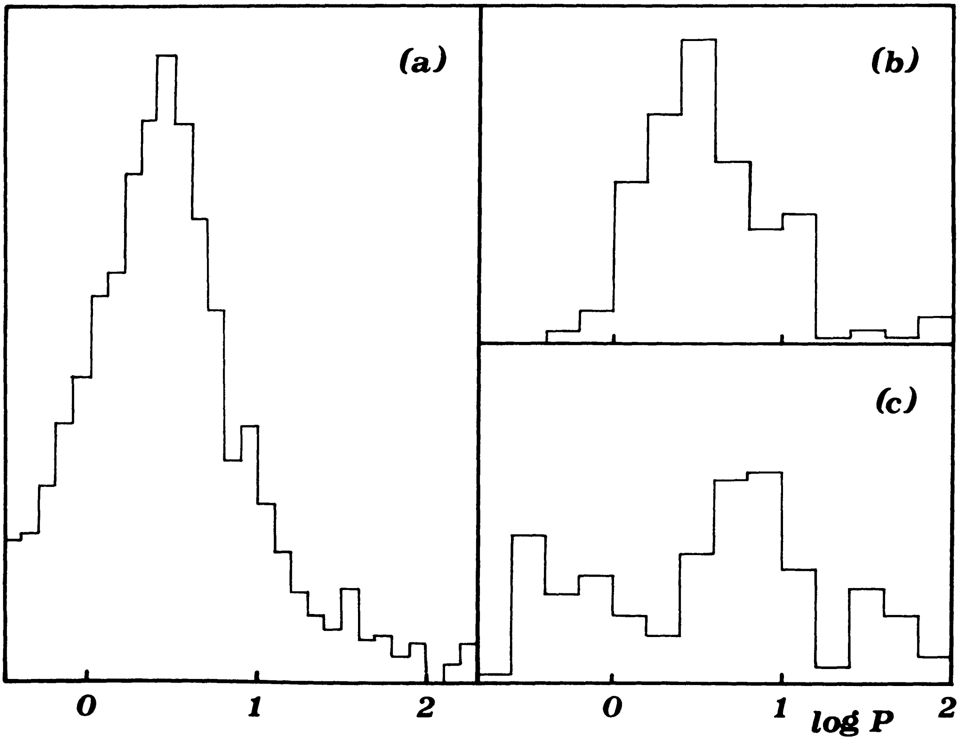
Another problem refers to the observational selection effect which clearly causes, for geometrical reasons, an overestimate of short-period systems (which more easily produce detectable eclipses). In Paper I the observed distribution for eclipsing binaries (which is similar to the one for spectroscopic systems) has been corrected in various ways, but the most relevant features, i.e. the main peak for periods of about 3 days and the presence of some secundary maxima, were unaffected and must be considered as real features.



*M. J. Plavec, D. M. Popper and R. K. Ulrich (eds.), Close Binary Stars: Observations and Interpretation, 23–26.*

The third correction method described in Paper I seems to be the most reliable. It employs the known geometrical properties of 140 systems as given by Giannone and Giannuzzi (1974) to evaluate the best-fit probability of observing the eclipse for each period interval. In this way we can estimate that the 3488 observed eclipsing systems could correspond to an available "real" sample of about 12,500 objects, whose distribution is richer of long-period systems than the observed one. This "corrected" distribution is shown in the Figure (case (a)), which allows a comparison with two similar histograms corresponding to systems of a given spectral type (cases (b) and (c); see the following). We remark that the normalization is not the same for the three distributions, which refer to original samples of respectively 3488 (a), 283 (b) and 117 (c) eclipsing systems.

In order to investigate in some more detail how the statistics of period is connected with the formation process and the evolutionary history of close binary systems, various methods are possible. We decided to employ the restricted sample formed by the 1248 systems




The figure compares the general corrected distribution for eclipsing systems (a) with the corrected distributions for systems containing B (b) and G (c) stars. The step in log P (days) is 0.1 in case (a) and 0.2 in cases (b) and (c).

https://doi.org/10.1017/S007418090006455X Published online by Cambridge University Press

for which the spectral type of at least one component is known, so that a separate analysis is feasible for different spectral types (see Paper II). Moreover, we tried to isolate the contribution to the distributions both of "evolved" systems (those containing a star of known luminosity class between the I and the IV) and of W UMa systems (whose statistical weight is probably amplified by observational selection). For each spectral class, the "geometrical" selection effect can be taken into account by the same method we used for the general distribution.

An inspection of the results leads to the following considerations. The distributions for early spectral types are rather narrow and show a single marked peak for periods of about 2 - 3 days, while moving towards advanced types the distributions become substantially broader (compare parts (b) and (c) of the Figure, which correspond to B and G stars respectively). Beyond the class F, we get clear evidence of bimodality (or perhaps plurimodality), with the original peak gradually displaced towards shorter periods (less than 1 day) and a new peak for longer periods that increases as the spectral type advances. This latter effect seems directly connected with the increasing contribution of evolved systems, especially for G, K and M classes; on the other hand, the W UMa systems give an important fraction of the short-period peak for F and later spectral classes. It is important to remark that all these conclusions are confirmed if we analyze the data with a smaller subdivision of spectral types (18 classes instead than 6). Moreover, observational selection does not seem to vitiate substantially the results (even if some features may be modified in a relevant way by the correcting method).

An interesting physical interpretation of the statistical results is possible if we study the dependence on spectral type of the average orbital separation of the systems (in units of the sum of stellar radii). If we assume that the systems are formed by two equal main sequence spherical components, we find that this quantity increases from about 1.5 (O types) to about 3 (late B types), then it remains approximately constant for a large range of spectral types (though in this range the absolute quantities - stellar radii and separations - change by a large factor) and finally, beyond early G types, it seems to grow rapidly.

We can try to connect these results with the current ideas about the origin and evolution of close binaries. An orbital separation of the order of 3 times the sum of the radii, which seems to be typical of most spectral types, could be the result of a common formation process for these systems, like the fission of a rapidly rotating protostar during the last phase of contraction : this conclusion is consistent with the results of recent numerical studies about the evolution of rotating collapsing clouds (Bodenheimer 1978). The increase of the average separation for the first spectral types could also be a by-product of the formation process (if the fission of more massive protostars results in smaller average separations), or it may

https://doi.org/10.1017/S007418090006455X Published online by Cambridge University Press

be an evolutionary effect. In this latter case, the effect could be due to the fact that more massive systems evolve more rapidly towards shorter periods, or to different average ages of systems with different spectral type. The timescale of the physical process responsible for the evolution should be of the order of $10^8$ yr, i.e. the maximum main sequence lifetime of the systems for which the effect appears.

Finally, the seeming increase of the average separation for systems of advanced spectral types is clearly determined by the high fraction of systems in which at least one of the components is subgiant or giant (so that our assumption about main sequence radii fails). On the other hand, the real increase of the mean period is consistent with the presence of theoretical and observational evidence about drastic changes undergone by "evolved" systems and due to the interaction of components.

## REFERENCES

Bodenheimer,P.: 1978, Astrophys.J. 224, pp. 488 - 496.
Farinella,P., and Paolicchi,P.: 1978, Astrophys. Space Sci. 54, pp. 389 - 406.
Farinella,P., Luzny,F., Mantegazza,L., and Paolicchi,P.: 1979, Astrophys. J., in press.
Fracastoro,G.: 1954, Mem. Soc. Astr. Ital. 25, pp. 347 - 382.
Giannone,P., and Giannuzzi, M.A.: 1974, Astrophys. Space Sci. 26, pp. 289 - 304.

## DISCUSSION FOLLOWING MANTEGAZZA, PAOLICCHI, FARINELLA AND LUZNY

Tutukov: There are many selection effects more: luminosity, the ratio of luminosities, the lifetime, evolution. What are the influences of those of your results?

Farinella: We agree that there are many selection effects. On the other hand, we think that luminosity and lifetime effects affect mainly the distribution of systems among different spectral types (even if they can lead to some wrong estimate of the percentage of evolved systems). The evolution and ratio-of-luminosities effects are obviously important mainly for the evolved systems, whose properties should be analyzed in much more detail than possible in a statistical survey. These effects probably decrease the statistical weight of late-stage systems, so that the reliability of our conclusions about formation and early evolution could be even strengthened.